BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: Laser calibration system for the STAR TPC and FTPC
Location: 1006

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:		
Name: Alexei Lebedev	*Signature:* Signature on File	*Date:*

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

C. Weilandics	Signature on File	
BNL LSO printed name	*Signature*	*Date*
Asher Etkin	Signature on File	
C-A Department ES&H Approval printed name	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
X Operation   X Maintenance   X Service   Specific Operation   Fiber Optics

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls.

LASER SYSTEM CHARACTERISTICS

Laser Type *(Argon, CO_2, etc.)*	Wavelengths	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
Spectra Physics, Nd:YAG, model GCR-130-10 , s/n 118, 1994	1064, 532, 266	4	290mJ@1064 30 mJ @266nm	5-8 ns	10Hz
Spectra Physics, Nd:YAG, model GCR-150-10, s/n 1367G, 1997	1064, 532, 266	4	600mJ@1064 50 mJ@266nm	5-8 ns	10 Hz
Uniphase, He-Ne, Model 155SL-1, s/n 301114	632	2	5 mW		CW

This system is using only 266 nm, other harmonics such as 1064 nm and 532 nm are used only by service engineer to check laser productivity and specifications. These harmonics are contained in beam dump load, supplied by Spectra Physics.

☐ **Cryogen Use**

Describe type, quantity, and use.

NA

☐ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

NA

☒ **Electrical Hazards**

Description *(Describe the power supply to the system).*

For Spectra Physics models both laser head and power supply contain electrical circuits operating at lethal voltage (~2kV) and high current levels. Only those trained in high voltage, high current electronics and who understand the circuitry of the GCR could service and repair the laser.

Even though both lasers are not under warranty from Spectra-Physics, laser component repairs such as laser head and power supply shall be provided only the by Spectra-Physics representatives. For this repair a controlled laser area shall be implemented

☐ **Other Special Equipment**

Description *(Equipment used with the laser[s]).*

NA

Laser System Configuration: Describe the system controls *(keys, switch panels, computer controls),* beam path, and optics *(provide a functional/block diagram for complicated beam paths)*.

STAR TPC and FTPC laser calibration system, which is integrated into the STAR detector currently located in Bldg. 1006. The calibration of the TPC and FTPC is accomplished by providing ionization tracks in their volume. There are ~500 narrow ultraviolet laser (UV) beams in the TPC volume and ~15 narrow ultraviolet laser beams in the FTPC volume. The produced ionization paths simulate straight tracks whose position is known with ~200 microns accuracy. The TPC and FTPCs share two class IV lasers, installed on the south side of the STAR magnet. The internal laser system contains a complete Nd:YAG laser with 1064 nm infrared (IR) output beam, which is transformed into 266 nm UV beam via harmonic doublers, one half-wave plate, a telescope and a Poisson ball. These elements define the wide laser beam and Poisson line. The Poisson line is utilized as a straight thin reference beam for installation and adjustment procedure of the optical elements. The set of optics for both TPC and FTPC includes entrance mirrors, corner mirrors, prisms and small rods with 1 mm mirrors. A flipper mirror allows one to direct the laser beam to the TPC or FTPC. Alignment and monitoring of the laser beam position is provided by the set of multi axis motorized mirrors and CCD cameras via remote control on a PC. Start and stop procedures for lasers are managed locally through control boxes or remotely from STAR control room by computer via Slow Control window, if all interlocks are in place.

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures
☐ Protective Housing Interlocks
☐ Other

☒ Beam Stop or Attenuator
☒ Key Controls

☒ Activation Warning System
☐ Other Interlocks

☐ Ventilation
☐ Emission Delay

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review, a copy of the design review documentation and written testing protocol must be on file. Completed interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

The STAR laser system is operated enclosed laser beams, during routine operation. Engineering approach to this mode is to entirely enclose all laser heads and all possible of laser beam paths to the optics and detectors. Laser head and initial optics are enclosed into big aluminum box with removable covers secured by screws. In Addition a steel rope with a lock is installed at each laser box. After the laser head the beam is directed to the TPC or to the FTPC and split inside these detectors into thin beams. All laser beams and fanout optics are enclosed in pipes and aluminum boxes. All connections between boxes and pipes are made with screws and clamps. To open these connections a special tool is necessary. This envelope structure remains solid and stable while TPC is in operational. This envelope structure allows simultaneously running the laser system and monitoring the TPC performance while electronics is repaired on the TPC face. Commercial beam stops from Spectra Physics (model BD-5) are installed at the exits of the laser head to absorb unused infrared and green harmonics, generated by doubling crystals. To direct the UV beam from laser output to the TPC we use 4 spectral line mirrors, designed for 266 nm, these mirrors completely eliminate IR and green harmonics from UV. Operation of this mode is completely safe, because all optics and lasers are enclosed.

For laser service and optics replacement in the laser system a mode with open laser beam requires a working laser controlled area. To provide a safe laser operation UV opaque fire resistant curtains are installed to provide a completely closed area. It would be used around the laser only in case of laser service. These curtains will cover entirely the east and west faces of STAR detector. It is very unlikely to install these curtains again, but they are ready at all times. For the laser service a smaller curtain is used to define a controlled area around the lasers themselves. Curtains are installed with a folding entrance to prevent laser beam escape from this area. Near the curtain area posts with red rope and warning labels are installed. Near the entrance a stand with warning light is installed. On this stand an infrared (IR) beam interlock is installed to prevent any unauthorized entrance into laser area with the laser operational.

See OPM 8.4 Att. CA-1006-1 Guidance for Alignment/Maintenance Operations
See OPM 8.4~ CA-1006-1 Interlock Test Checklist

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☐ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

For normal routine operation, lasers are enclosed with aluminum boxes, pipes and laser beam optics enclosures. Standard warning labels approved by RHIC Safety management and the BNL-LSO are used. Additional warning labels, containing information about lasers, power, output energy, etc are installed on boxes with the laser head on both sides of STAR detector. Also a list of contact persons is posted on laser box. A steel rope with locks prevents unauthorized access to these boxes.

See OPM 8.4 Att. CA-1006-1 Guidance for Normal Operations

Alignment and service of laser with open beam requires additional administrative precautions. A temporary laser controlled area is created near the laser, with shielding, interlocks and warning lights. Additionally to these measures several stands with red rope and warning labels are installed defining the laser control area.
During RHIC operation and when access to Wide Angle Hall with STAR detector is prohibited, laser operation is only possible through Slow Control window from the Control room. At this point any trained Detector Operator can operate the laser without laser specific training.

See OPM 8.4 Att. CA-1006-1 Guidance for Alignment/Maintenance Operations

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

See OPM 8.4~ CA-1006-1 Configuration Control Checklist

PERSONAL PROTECTIVE EQUIPMENT

☒ Skin Protection ☐ Eye Wear

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color -coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

STAR laser system is using only 2 wavelengths- 1064 nm during laser calibration and service and 266 nm during routine laser operation. Green harmonic with wavelength 532 nm totally absorbed in beam dump, installed on laser head. During laser service with IR beam only a special diffuse screen or photograph paper are used to align the resonator. Construction of laser box prevents any possibility to have direct IR beam into human eye. From this we could conclude a safe operation with IR beam.
For the UV beam with diameter ~8 mm we have a maximum 60 mJ pulse. At the same time we have much more strong attenuation goggles with OD=+15.

The following are the optical density requirements for the laser operation; they are based on the maximum stated outputs for the 1064nm and 266nm beams. The direct 1064nm beam is not accessed by the user.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

EYE WEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
Spectra Physics, Nd:YAG, model GCR-130-10	1064 nm	OD 5.66 (10 sec.)	OD 2.61 (600 sec.)	4.03 meters	
	266 nm	*OD 3.3 (10 sec.)	OD 1.7 (600 sec.)	1.4 meters	
Spectra Physics, Nd:YAG, model GCR-150-10	1064 nm	OD 6 (10 sec.)	OD 2.9 (600 sec.)	5.8 meters	
	266 nm	*OD 3.52 (10 sec.)	OD 1.9 (600 sec.)	1.8 meters	
Uniphase, He-Ne	Uniphase, He-Ne	NA	NA		

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

EYE WEAR SPECIFICATIONS		
Laser System Eyewear Identification	Wavelengths	Optical Density
UVEX	1060 nm	OD 5+ @1060nm
GPT	266 nm	OD 15+ @332 nm

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL World Wide Web based training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

See BTMS

See OPM 8.4~ CA-1006-1 Configuration Control Checklist – Normal Operation

Prior to energizing the laser under normal conditions the operator should make a visual inspection of the laser housing and the transfer tube from the lasers to TPC an FTPC.

See OPM 8.4~ CA-1006-1 Configuration Control Checklist – Alignment Operation

Prior to energizing the laser under alignment conditions the operator should:

1.Set up the warning signs around the tent area.

2. Verify that the integrity of the tent and verify that it is fully closed.

3. Illuminate the laser warning sign at the entrance to the tent.

2. Check the IR interlock at the entrance to the tent, make a note in laser log book.

OPM 8.4 Att. CA-1006-1 Guidance for Normal Operations

Procedures

Normal Operations: (any trained laser operator may operate the system)

1. Get laser ignition key from the STAR key cabinet in the trailer.
2. Check the integrity of the laser enclosure and the beam path to the TPC and the FTPC.
3. Check the flammable gas interlock
4. Put key into laser ignition and turn.
5. Energize lasers through the SLOW CONTROL window in computer in control room.
6. Verify alignment of lasers using electronic sensors.
7. Fine tune alignment of the laser beam with the remote actuators.
8.

OPM 8.4 Att. CA-1006-1 Guidance for Alignment Operations

Alignment and Maintenance Procedures:

1. Set up laser warning signs
2. Set up the laser curtain and verify that all direct lines of sight to the laser beams are blocked.
3. Set out the illuminated laser-in-use sign at the access point to the tent.
4. Set out the IR beam interlock at the access point.
5. Get the laser ignition key from the STAR key cabinet in the trailer.
6. Remove all jewelry and watches.
7. Check and put on laser safety goggles.
8. Insert laser ignition key and energize the laser.

Beyond this step, procedures are specific for the given task. The procedure for the initial alignment is outlined here: First, the steering EXIT mirror at the exit of the laser housing is adjusted via remote piezoelectric drivers to direct a beam to the entrance mirror in box D. A special target-cross is installed in face of the entrance mirror to ease alignment. The steering mirror is manually adjusted to make the target-cross and the Poisson coincide. Once this process is complete, a wide laser beam (~25 mm diameter) is steered by the KNEE mirror to ½" mirrors to divide wide beam into 3 beams ~8 mm diameter. Each small beam is directed to designated TPC and FTPC corner mirrors. After this each small beam shines on a small ceramic rod with five 1 mm mirrors. These mirrors create thin laser beams to calibrate TPC and FTPC. After this procedure the position of wide and small beams is fixed on CCD cameras and in the future, realignment will be performed only by piezo drivers on EXIT and KNEE mirrors. After the first alignment all laser beams on the TPC and FTPC wheel are enclosed into Al pipes. Additional details may be found in an available scientific summary of this procedure (see *Laser Calibration System for the STAR TPC*, M. Alyushin *et al*. IEEE Nuclear Science Symposium, Anaheim CA, Nov 2-9, 1996, N27-33).

Maintanance of laser system

Specially trained and/or certified laboratory personnel will maintain the laser equipment. All relief devices, safety interlocks, alarms, and other hazard prevention devices will be maintained, calibrated and tested for functionality on a regular basis in accordance with standard industrial practices and recommendations of the manufacturers**.**

Prior to initial operation after an extended shutdown the laser and beam transport enclosures shall be inspected for integrity by a trained operator in addition after the a pole piece has been removed the associated enclosures shall be inspected prior to inserting the pole piece.

TO BE REPLACED BY Laser Specific JTA in BTMS

Qualified Laser Operators:

Basic Laser Training	Job-Specific Training *	Medical Surveillance	Printed Name	Signature	Owner/Oper. Initial/date
		12/11/1997	Alexei Lebedev, 21605		